was reduced to 5 miles. It seemed to disappear at nightfall and was not again observed.

These extracts from station reports are intended to show the approximate maximum spread of the dust from day to day. The stations were chosen at the eastern limits of the phenomenon on the dates reported.

After May 1934 the extremely dry conditions that made such widespread dust storms possible began to be alleviated to some extent. Moderate to fairly generous rains were rather general over much of the region covered by the dry condition of the soil and, even where they were not sufficient to break the drought in a real sense, they were sufficiently heavy to lay the dust in many places and thus tended to a more stable soil condition.

After May, while there were some dust storms, they were mostly moderate in character and were more or less local in extent. The reports of the various sections, as rendered to the Central Office, carry very few references to dust storms.

As a postscript to the above, it is interesting to note that the region mentioned as extremely dry in January continued so until the first of March, with severe dust storms reported throughout. The dust storms were rather widespread within the dry sections and became increasingly frequent toward the last of February and the first of March. Finally, they were of such intensity that appreciable dust was reported as far east as the Atlantic coast on March 6 or 7.

EFFECTS OF LOCAL SMOKE ON THE CLIMATE OF NASHVILLE, TENN.

By FOSTER V. JONES

[Weather Bureau, Nashville, Tenn., January 1935]

Few cities in the United States have a greater smoke nuisance to contend with during the winter months than Nashville, Tenn. Frequently during this season, dense smoke extending about 250 feet in height blankets the downtown section of the city for approximately a 4-mile radius from the Weather Bureau office. It has been so dense on occasions that the visibility was reduced to zero, the sun's disk invisible from street level, and street and automobile lights kept burning until after 10 a. m., although at the same time just outside the smoke area the sky and air were brilliantly clear.

The formation of this smoke shroud over the city is directly dependent on meteorological conditions, which when combined with local geographical features form a perfect union for stagnation of the lower atmosphere. Nashville is situated in a bowl completely surrounded by a rim of hills 300 or more feet high, and traversed diagonally by the Cumberland River. It has been observed that the smoke does not form when the wind velocity, as measured by the Weather Bureau anemometer 188 feet above the ground, exceeds 8 miles per hour. Velocities lower than 8 miles generally occur when a slow moving southeastern HIGH overspreads Tennessee, at which time the wind lulls and the temperature falls rapidly to a critical point.

The only available records of the density of smoke at Nashville were made by R. M. Williamson during the several winters beginning 1927–28. The results were included in a paper read before the Tennessee Academy of Science and published later in the Journal of the Tennessee Academy of Science.[1] Williamson's statement in part is as follows:

The observations were made from the Weather Bureau office, in the Stahlman Building, and concerned the density of smoke as observed from that point, and at the hours 7 a. m., 9 a. m., 12 noon, and 4 p. m. Records were made during February and March each 4 years, December and January each 3 years, and November 2 years. Density was graded on the Ringelmann scale, as published and used by the United States Geological Survey. * * * The following table gives the monthly averages for the 4 winters at the hours specified.

Month	7 a. m.	9 a. m.	12 noon	4 p. m.
November	2.0	1.5	1.0	1.2
December	2.3	2.1	1.5	1.4
January	2.1	1.9	1.5	1.2
February	2.1	1.8	1.2	1.1
March	1.3	1.0	0.4	0.2
Winter	2.0	1.7	1.1	1.0

The percentages for the winter were, respectively, 40, 34, 22, 20.

These figures indicate the much greater prevalence of smoke in the early morning hours than in the afternoon. They show a gradual diminution of smoke from a maximum at about 7 a. m. to a minimum about the middle of the afternoon. This corresponds in a general way to the diurnal march of average wind velocity, for smokiness and wind velocity are very closely related. The density of smoke is, as a rule, in inverse proportion to the velocity of wind. It is least dense in the afternoon, at which time average wind velocities are highest. It is most dense in the early morning, for then the atmosphere is in its most quiescent state, unless, of course, there is active storm movement. Smoke will clear away often during times of rapidly rising temperature, due to turbulence in the atmosphere created by rising currents. The smoke is then lifted to elevations where it is carried away by the upper horizontal currents, while at the surface there may still be but little lateral movement. The presence of smoke in varying degree in different parts of the city, while dependent to some extent upon the number and size of the chimneys from which it comes, is also dependent upon the direction of the wind at the time. The detailed records show that there was some smoke nearly every day in the winter months, although there were several periods of 3 or 4 consecutive days when none was observed.

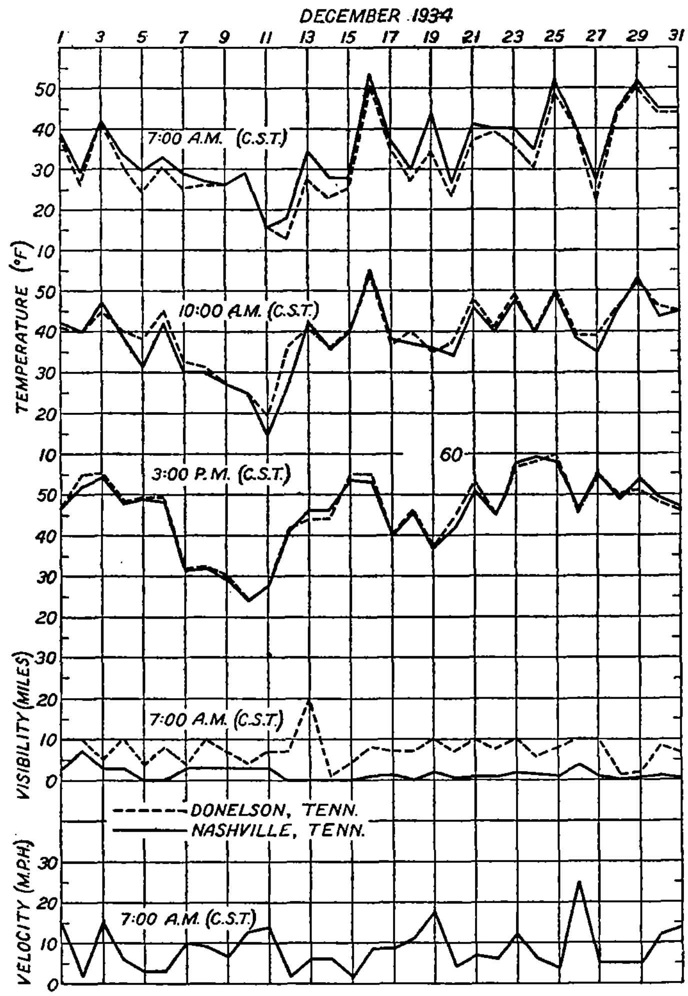
In addition to decreasing the visibility, the smoke layer holds the city minimum temperature considerably higher than that of the immediate vicinity. While there are many advantages in having a higher city temperature, there are many technical objections to this feature. The high downtown temperatures are those telegraphed and those upon which the local forecaster must base his forecasts and verification. It is also objectionable to give the public official temperatures, for the city as a whole, that are artificial, when the public knows from the freezing effects that the temperature must have been lower.

Some readers may think that a difference of a few degrees has little significance. In the Southern States the situation is quite different from that farther north, where freezes are almost a daily occurrence. Southern homes are not built to stand long spells of severe winter weather. Produce dealers often leave carloads of perishable goods unprotected. Farmers depend on temperatures near freezing for the killing of their winter meat supply. Therefore, a very definite critical temperature is reached at 32°, and continues down to 10°. These few degrees mean profit or loss and should be forecast as accurately as possible.

The attached graphs of the temperature, visibility, and wind velocity show the difference during the month of December 1934. There was no particular reason for choosing the month of December 1934, except that the data were more readily available and the work could be done from day to day; thus we have an arbitrary period in which typical effects are represented, although differences at this season are not nearly of so great a commercial

[1] Williamson, R. M.—Visibility, A New Element in Meteorological Observation. (Read before the Tennessee Academy of Science, Nov. 26, 1932, and published in the journal of that society.)

value as those of early spring and late fall. The records are from the temperatures taken at the Nashville Weather Bureau located in the heart of the city, and the Airways Radio Station located at Donelson, 10 miles east of the Weather Bureau. The thermometers at Nashville are 168 feet above the ground—653 feet above m. s. l., and those at Donelson 5 feet above the ground—625 feet above m. s. l.; thus the instruments are nearly in the same plane. A partial record was kept at the writer's residence 3½ miles northeast of the city office, 500 feet above m. s. l. but beyond the rim of hills and the smoke blanket. The temperature and visibility were found to be in close agreement with that of Donelson, with a tendency to slightly



lower, however; this was attributed to the more open exposure of the thermometer.

On the graphs the most typical smoke condition is noted on the fifth. A mass of polar air had overspread the State, the sky was clear and the air transparent. The visibility was reduced to zero at Nashville and to 4 miles at Donelson at 7 a. m. The low visibility at Donelson was the result of a light fog along Stones River, which runs in a valley 1 mile east of the station, in combination with the settling of the smoke particles carried by the eastward drift of the intermediate atmosphere from the city of Nashville. After 7 a. m. the city usually begins "firing-up" in earnest, and this morning was not an exception. Automobile and street lights were necessary until 10 a. m., and the sun's disk was not visible from the street at intervals, but was always visible from the Weather Bureau office on the twelfth floor of an office building. The temperature remained nearly stationary within the city until the smoke had absorbed enough of the sun's radiation for the mass to become warmer than the surrounding air and ascend to heights where the wind was sufficient to carry it away. This was about 10 a. m. During this interval Donelson's temperature had risen from 6° below that of Nashville to a point 6° above. However, as soon as good circulation began the temperatures became equalized, as is shown by the graph as of 3 p. m.

A like condition is shown on the 12th; in this case the temperature at Donelson rose from a point 5° below that of Nashville to 9° above, or an increase of 23°, while Nashville was gaining 9°. It must be remembered that the Nashville temperatures are taken 168 feet above the surface, which is often near the top of the smoke layer, and the conditions would be magnified at street level. As previously stated, the main commercial interest is in temperatures that are lower than those of the city; and as can be observed from the graphs, conditions are reversed before and after sunrise; i. e., before sun-up the smoke prevents surface cooling by radiation, and after sunrise acts as an insulator between the sun and the surface.

During the month of October 1934 there were three periods of large differences in temperature between the city and the suburbs. On the mornings of the 14th and 26th, light frosts were observed in the suburbs, when the city minimum temperatures were 46° and 49°, respectively. During the period October 28–30, a large mass of Arctic air overspread the southeast. The atmosphere was transparent and the sky clear, but a thick smoke blanketed the city on all three mornings. The city temperatures were 36°, 35°, and 39°. During this time ice was noticed in all the suburbs and on the morning of the 29th was about one-fourth of an inch in thickness. There were some reports of automobile radiators freezing; there were no suburban temperatures kept at the time, so it is impossible to state the exact minimum reached, but from the freezing effects, which killed vegetation, temperatures must have been below freezing to a considerable extent, and those of the immediate downtown section kept up because of the smoke layer.

On the morning of January 3, 1935, the temperatures at Nashville was 35° (3° above freezing), and at Donelson 23°, or 9° below freezing; at the same time the temperature within the suburbs was 24°. Smoke over the city was very dense, making lights necessary, but it was estimated to extend only a few feet above the Weather Bureau roof. Visibility was practically unlimited beyond the city.

Comparative averages, winter of 1933–34

MEAN TEMPERATURE, °F.

	December 1933		January 1934		February 1934		March 1934	
	7 a. m.	10 a. m.	7 a. m.	10 a. m.	7 a. m.	10 a. m.	7 a. m.	10 a. m.
Nashville	44.4	48.2	37.9	40.6	29.9	35.0	40.8	45.6
Donelson	41.9	48.4	36.3	42.0	27.7	36.0	38.7	47.6

VISIBILITY, IN MILES

Nashville	0.6	[1] 3	0.3	[1] 6	0.6	[1] 3	0.6	[1] 6
Donelson	5	5	5	5	4	5	6	7

[1] At noon.

Highway contractors appreciate accurate temperatures near the surface when laying concrete and more especially certain forms of asphalt which cannot be laid when the temperature is less than 45°. Frost conditions are of the utmost importance at certain seasons and forecasts cannot be accurately made from city temperatures thus affected. Shippers' forecasts should cover the terrain over which the shipment is transported, and should be verified from country and not city temperatures.

Visibility from a city office is like the proverbial "drop in a bucket" insofar as the surrounding country is concerned. From the aeronautical standpoint, it is of little value; in view of the present trend of aircraft, it may be some time before we land in the heart of cities to any great extent. Certainly this visibility cannot be used to determine questionable air masses.

Although only a few instances have been cited and the length of comparative records is short, it can be readily seen that smoke has a definite influence on the climatic features of Nashville. A similar problem will be found in a large number of our Southern cities and presents an item for further investigation.

ICE CRYSTALS AND HALO PHENOMENA

By B. W. CURRIE

[University of Saskatchewan, Saskatoon, Saskatchewan, Canada, March 1935]

Vertical pillars of light frequently are seen during the winter months above street lights, electric advertising signs, and airport beacons in Western Canadian cities.[1] These pillars are caused by reflection of light to the observer from falling ice crystals between him and the light source. Essentially this is a halo phenomenon, and one for which the form and the size of the ice crystals, and the accompanying atmospheric conditions, can be observed.

The color of the light from the pillars, and its state of polarization, show that they are caused by reflection. The color of each pillar is exactly the same as that of the light below it; the red pillars from the neon electric signs are particularly noticeable. The light from the pillars due to distant street lights shows no polarization, while the light from the top of the pillars produced by near street lights shows polarization in a vertical plane. Evidently, if the observer is close enough to a street light, a portion of the light forming the top of the pillar is reflected from the ice crystals at angles close to the polarizing angle.

Figure 1 shows an artificial light display. The apparent height of a pillar increases with the intensity of the light source. Calculations based on known distances to light sources and the measured sizes of the corresponding pillars on photographs often give heights in excess of 1,100 feet. When the wind velocity is greater than 8 to 12 miles per hour, only the brightest lights have pillars, and these are always low and faint.

Whenever the pillars are seen, the falling ice crystals are caught on a glass plate and photographed by transmitted light, a 1-inch microscope objective being used for a photographic lens. In this way images of 40 to 70 crystals are obtained by a single exposure, and these may be examined and measured later. Two kinds of crystals—thin hexagonal plates and thin broken fragments of snowflakes—cause the pillars. Only the first kind is found on calm nights when the most brilliant displays occur. Figure 2 shows several typical crystals. A tenth-millimeter scale magnified the same as the crystals indicates their size. The mean maximum distance between opposite sides of 61 crystals photographed at Saskatoon, Canada, on the evening of January 23, 1935, was 0.071 mm. Individual values ranged from 0.14 to 0.03 mm. Occasionally two crystals will freeze together (as shown in figure 2), and the thickness can be measured. The mean thickness of 18 crystals was 0.016 mm, extreme values ranging from 0.025 to 0.01 mm. Rounding of the edges due to melting will tend to make this value too large.

Both kinds of crystals may be found when the pillars are seen on windy nights. However, the second kind alone can cause the pillars. They are snowflakes broken by the wind, and are of many shapes and sizes; diameters below 1 mm predominate. Incidentally, pillars have never been observed when unbroken snowflakes are falling.

Hexagonal plates more than 0.1 mm across have been observed so far only once. This was on November 18, 1932, at the Canadian International Polar Year station near Chesterfield Inlet, when a brilliant pillar was seen above a light outside the Roman Catholic Mission Hospital. The mean diameter of the plates was 0.14 mm; extreme sizes ranged up to 0.8 mm. This was the only time during the year at Chesterfield that an artificial light pillar was observed, and was also the only time when an observed crystal fall consisted of plates alone. Generally the falls were a mixture of plates, needles, combinations of the two, and needles with pyramidal ends.

Observations show that the crystals which cause the artificial light pillars are also responsible for solar and lunar pillars, and 22° halos. If the moon is visible at the time of an artificial light pillar display, a faint pillar extending above and below the moon can be seen. A solar 22° halo and pillar were observed simultaneously at the secondary auroral station, 20 miles south of Chesterfield, on January 24, 1933. A 15- to 20-mile wind was sweeping the crystal cloud along the earth's surface, and the sun was just above the horizon. The upper portion of the 22° halo was seen as a circle projected on the sky, and the lower portion as a parabola projected on the earth's surface. The pillar above the sun was faint, and may have extended below the sun, but it could not be distinguished from the light reflected from the snow surface. Incidentally a distinct difference exists between the parabola[2] observed in this case and that frequently seen from frost formations or crystals on the earth's surface, the illumination inside the parabola being much brighter because of the light reflected from the snow surface. The crystals were found to be mostly thin plates when examined by the lens on the auroral camera (the only lens available). Their size was considerably less than 1 mm.

Weather conditions during artificial light displays vary greatly. Wind velocities less than 8 miles per hour seem essential to the formation of bright pillars. If snow is falling, the pillars can be seen only if the wind is strong enough to break the snowflakes. Temperature conditions show no uniformity, partly because the crystals are formed at higher levels and then fall to the surface. The temperature changes leading up to the two displays already mentioned contrast sharply with each other. At Chesterfield the temperature dropped 10.8° F. between 14 : 50 h.

[1] Nature, 1930, vol. 125, p. 526.

[2] Die Haloerscheinungen, by R. Meyer, pp. 73-74.